24 March 1964

DEVELOPMENT OBJECTIVES

ADVANCED FILM-VIEWING LIGHT TABLE WITH A TRANSLATING MICROSCOPE CARRIAGE

1. INTRODUCTION.

These development objectives describe the requirements to be met in the design and development of an advanced film-viewing light table with a translating microscope carriage. The proposed table would replace the current models which cannot be adjusted to accommodate different operators. The present tables are generally awkward and uncomfortable to use and do not provide adequate illumination.

2. CONCEPT.

This table is intended to provide ease of viewing, increased illumination, easy loading, an advanced film transport system and a superior method of translating a microscope over the viewing area of the table. It is to be as light, compact and simple in mechanical design as is possible within the parameters imposed by the specific requirements stated in these objectives.

3. GENERAL DESCRIPTION.

This table shall provide an 11" by 40" illuminated area for use in viewing single rolls of $9\frac{1}{2}$", 5" or 70mm film, or two rolls of either 5" or 70mm film. This unit will normally be positioned on an elevating or low, fixed table with the unit's viewing surface in a horizontal position, the long dimension extending to the right and left of the operator. The operator will work at the table as he would sit (or stand) at his own desk. Most operators prefer to position a viewer close to the edge nearest their side of the supporting table. A movable carriage shall afford translation of a microscope over the viewing area.

4. REQUIREMENTS.

4.1. Illumination System.

4.1.1. Intensity.

4.1.1.1. Range. At full intensity the illumination system must provide at least 1700 foot-lamberts measured at the illumination surface. 2000 lamberts is a definite design goal. Illumination shall not vary by more than 10% between any two points on the entire illuminated surface.

4.1.1.2. Variability. The intensity of illumination shall be continuously variable through a range of 15% to 100% of full intensity without visible evidence of "flicker".

4.1.2. Heat. The light table must be able to be operated continuously at maximum intensity over a 24-hour period, in a room with an 80°F ambient temperature, without exceeding 110°F on any external surface.

4.1.3. Diffuser. An opal glass or similar diffuser shall be located between the light source and the clear glass top.

4.1.4. Shades. Adjustable shades must be provided to mask out all of the viewing surface not actually covered by film. Each of these shades must be located beneath the surface glass, mounted along the long dimension of the unit and extendible across the short dimension. This extensibility must be continuously variable between a minimum extension of (0) zero inches and a maximum extension of 9 inches. These shades must not encroach upon the illuminated viewing area when retracted and, in addition, must be able to be locked in any extended or retracted position.

4.2. External Configuration. 55x20x7

4.2.1. Size. The entire unit shall not exceed 55" in length and 20" in width. Width is exclusive of the crank handles but includes all the components of the translating carriage. The overall height of the light table shall not exceed 7" (minus the carriage, scope and reels). The carriage height shall be kept at a minimum.

4.2.2. Weight. The unit must be as light as possible without sacrificing good stability.

4.2.3. Height Adjustment. A superior adjustment system must be provided so that the entire table can be raised or lowered 3 inches.

4.2.4. Tilt Mechanism. A means must be provided for a 0° through 15° back-to-front tilt of the light table about its long axis. This motion must be simple, smooth, positive and must be able to be locked at any angular tilt within this range.

4.2.5. Comfortable Viewing Position. The light table, the translating carriage and the microscope adapter mounts must be designed to place each of the microscopes at a comfortable viewing height and in a comfortable working position. Human engineering factors should count strongly in the new design. It is understood, of course, that these positions also depend on the height of the illuminated surface, the requirement for the carriage to adequately clear the film and the varying working distances of the microscopes.

4.3. Spool Loading and Holding Mechanism.

4.3.1. Loading Mechanism. A means for the fast loading and unloading of single spools of 9½", 5" and 70mm film or two rolls of either 5" or 70mm must be provided. Rolls will range up to, and including, 500-feet capacity. This loading system must operate quickly and at the same time be positive in action: i.e., it must not drop the heaviest full spool (9½", 500 feet) no matter how fast or hard the film is cranked. A drop-in film loading system is desirable.

4.3.2. Holding Mechanism. The holding mechanism which engages and secures the spool must be designed for easy one-hand operation -- so that the film can be held in one hand while the holding mechanism is activated with the other. A positive and yet quick release lock must be incorporated.

4.4. Film Transport.

4.4.1. General. A unique film transport system shall permit bi-directional film motion controllable from either end: i.e., it will permit both winding and unwinding with the same crank at one end of the table. This transport system may be either mechanical or electro-mechanical; however, basic simplicity of design and complete reliability are mandatory. Consequently, a purely mechanical system is more desirable.

4.4.2. Film Capacity. The film transport system must accommodate either single rolls of 9½", 5" or 70mm-wide film on either partially- or fully-loaded spools of up to, and including, 500-foot capacity. In addition,

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provision must be made for handling two rolls of either 5" or 70mm film simultaneously. These rolls should be mounted side by side with a supporting post in between.

4.4.3. Film Direction. Film spools shall be located at both ends of the long dimension of the viewing area, with the film or films transported along (and parallel to) the long axis of the light table. When two rolls are used, the film strips will travel parallel to each other and to the long axis of the table, with a minimum of separation between strips.

4.4.4. Rollers. Rollers must be designed so that film can be transported either emulsion-up or emulsion-down without scratching. Either the rollers must be segmented or some alternative system provided so that when two rolls of film are used, the alternate rolls can be wound in opposite directions concurrently or one of the two rolls translated while the other roll remains stationary.

4.4.5. Film Tension. The film transport mechanism must maintain a light, constant, even tension on the film or films -- just enough to keep the film flat and in contact with the plate glass surface when the film is stationary. This tension should be automatically reduced or eased when the film is moved.

4.4.6. Film Drive.

4.4.6.1. Drive Modes. The film drive must: wind and unwind single rolls of $9\frac{1}{2}$"-, 5"- or 70mm-wide film or two rolls of either 5" or 70mm film; be capable of winding one of the dual rolls while unwinding the alternate roll and/or permit one roll to remain stationary while the other roll is translated.

4.4.6.2. Drive Control. The drive control may be a hand crank or electrical switch; however, if an electrical control is used, it must provide the same degree of control sensitivity as a hand crank.

4.4.6.2. Dual Speed Range. A dual speed range with a high or "slew" speed shall be provided. This could be in the form of a two-speed, mechanical gear shift, a two-speed electrical motor, a variable lever arm crank or an electro-mechanical approach.

4.4.6.3. Reliability and efficiency. Whatever the system, it must be very reliable. Each individual hand crank must wind or unwind film very smoothly -- from either its own spool or the spool at the other end of the table. The drive must be a low-friction system which incorporates inertia damping and antibacklash features. The efficiency, reliability and ease of operation of this drive system is one of the most important considerations in this development.

4.5. Translating Microscope Carriage.

4.5.1. General. A carriage shall be provided for translating a stereo-microscope or microstereoscope in both X- and Y-directions over the illuminated format.

4.5.2. Amount of Translation. The optical center of the microscope shall scan an area of 10" by 35". This area shall be centered in the illuminated area, across the short dimension, and shall commence one-half inch from the right-hand edge of the illuminated area. (The right-hand edge refers to the operator's right as he faces the light table.)

4.5.3. Adapters must be provided for mounting three separate microscopes: [redacted] They must permit a rapid but stable mounting of any of the above units (with their attendant focusing mechanisms) upon the translating carriage. In addition, this mounting must permit an 180° rotation of each scope so that it may be used parallel to either the X- or Y-axis of the light table and from either long side.

4.5.3.1. Carriage Motion. The carriage motion must be a smooth, positive, low-friction motion which is free of vibration ("chatter"). The friction load must be consistent throughout its range: i.e., a consistent pressure results in a consistent motion with no position of lesser or greater resistance.

4.5.3.2. Locks. Positive locks must be provided to lock the carriage in X and Y at any position of its 10" by 36" travel.

4.5.3.3. Fine Micrometer Motion. A fine micrometer X- and Y-microscope motion must be provided. The total travel of this motion must be ±2cm. in both X and Y. This motion shall be a precision, auxiliary motion accomplished once the main translational carriages have been locked in position. This precision motion must be graduated and easily readable. The motion shall be accurate to .001 mm plus .01% of the total distance being measured with a least count of .0005 mm.

4.5.3.4. Rigidity. It is mandatory that the carriage ways be of rigid construction to insure perpendicularity of the X- and Y-axis. These ways (or tracks) must be perpendicular and parallel to the extent that, when one end of the Y track is locked (so that it can not move in X) and a pressure of 5 pounds is applied to the other end (longest possible lever arm) of the Y track, it will not deflect more than .002 inches.

4.6. Miscellaneous.

4.6.1. Construction. Construction shall meet the highest commercial standards.

4.6.2. Shock Hazard. The unit must be grounded and free of all shock hazards.

4.6.3. Warning Light. A warning light must be provided to show when the unit is on even if the (table) light intensity is turned completely down.

4.6.4. Controls. All operational controls must be conveniently located and readily accessible to the operator. Human engineering factors must be thoroughly considered in the design and placement of these controls.

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1. where do the spec not definitive - thus causing additional work

2. Where did we do work not covered by the spec

3. Where did Human Factors considerations cause additional work due to
   - breadboards
   - changes
   - improvements
   - oversights

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4. All changes are not significant in themselves but cause other changes therefore making it difficult to cost.

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5. [redacted] does not want to make a statement to contracts that involves the technical people

Table 1

DEVELOPMENT OBJECTIVE

AN ADVANCED TILT TOP LIGHT TABLE

1. INTRODUCTION

These development objectives describe the requirements to be met in the designing of an Advanced Tilt Top Light Table. This table is intended as a replacement for contemporary tables which tend to be awkward and uncomfortable to use. They provide inadequate light and, in most instances, require the operator to adjust to the limitations of the table rather than adjusting the table to the operator.

Note these are development objectives or goals

2. CONCEPT

This table is intended to provide ease of viewing, increased illumination, easy loading and a superior film transport system. It is to be as light, compact and simple in mechanical design as is possible within the parameters imposed by the specific requirements stated in these objectives.

No comment

3. GENERAL DESCRIPTION

This table shall provide a 11" by 18" illuminated area for use in viewing single rolls of 9 1/2", 5", or 70mm film, or dual rolls of either 5" or 70mm film concurrently. The light table in tilted configuration will normally be positioned facing the operator on the front or forward edge of a low, fixed or elevating table. The viewing surface will normally be tilted about the center of the shorter axis of the light box; however, the table may be used in a horizontal position or tilted about the long axis of the table.

This specifies three standard film types 9 1/2", 5" and 70mm. Since we were told they also use other film sizes our design provides continuous adjustment. Three fixed positions would have been easier but our table is more flexible in this characteristic than outlined in the specification.

4. REQUIREMENTS

4.1 Illumination System

4.1.1. Intensity.

4.1.1.1. Range. The illumination system must provide at least 1500 foot lamberts, (measured at the illumination surface) with 1800 foot lamberts a definite design goal. This illumination shall not vary by more than 10% between any two points within the entire illuminated surface area.

Our table provided 2500 foot lamberts of illumination at a uniformity of 2.4%. This is 40% higher illumination and 400% better uniformity than the goals set out in the specification.

4.1.1.2. Variability. The illumination intensity shall be continuously variable throughout a range of from 15% to 100% of full intensity without evidence of "flicker."

We delivered a table which provides a variable illumination of 0.4% to 100% of maximum without evidence of flicker. This is 37 times better than the design goal.

4.1.2. Heat. The light table must be able to be operated continuously at maximum intensity over a 24 hour period in a room with an 80°F ambient temperature, without exceeding 110° on any external surface.

No comment

4.1.3. Diffuser. An opal glass or similar diffuser shall be located between the glass top and the light source.

Our table used an acrylic plastic diffuser which is equivalent to those mentioned.

4.1.4. Shades. Adjustable shades must be provided to block out all of the illuminated surface not actually covered by the film. Each of these shades must be located beneath the surface glass, mounted along the long dimension of the unit and extendable across the short dimension. This extensibility must be continuously variable between a minimum extension of (0) zero inches and a maximum extension of 9 inches. These shades must not encroach upon the illuminated viewing area when retracted and, in addition, must be lockable in any extended or retracted position.

We also provided a center shade to mask the space between two film strips. This added feature is an improvement but not defined in the specification.

4.2. <u>External Configuration</u>

4.2.1. Size. The entire unit shall not exceed 32" in length and 16" in width. Width is exclusive of crank handles. The overall height of the table shall not exceed 9" when in the horizontal position. This is the height excluding the film spools.

No comment

4.2.2. Weight. The unit must be as light as possible commensurate with that weight which is necessary to maintain good stability and to balance the table in any of its tilted positions.

Ambiguous

4.3. Spool Loading and Holding Mechanism.

The specification was not definitive regarding the film spool type which has a direct bearing on the design of the holding mechanism.

4.3.1. Loading Mechanism. A loading mechanism must be provided for the fast loading and unloading of single spools of 9 1/2", 5" and 70mm film or dual rolls of either 5" or 70mm. These rolls will range up to and including 500 feet in capacity. The loading system must be both quick and easy to operate and at the same time positive in action; i.e. it must not drop the heaviest full spool (9 1/2", 500 ft.) no matter what the degree of tilt of the table or how fast or hard the film is cranked. A drop-in film loading device is one possibility.

4.3.2. Holding Mechanism. The holding mechanism which engages and secures the spool must be designed for easy one hand operation so that the film can be held in one hand while the holding mechanism is activated with the other. A positive but quick release lock must be provided on this securing device.

This mechanism was designed and a model fabricated to demonstrate the action to the customer. This service was given to the customer but was not included in our proposal cost estimates. We did this additional work because the reel holding mechanism was one of the areas of customer concern and weaknesses in present equipment which we wanted to provide an approved solution.

4.4. Film Transport

A mechanical system was designed because of the simplicity and also because it provides the operator with maximum control of the film position at all speeds. While the basic design in our film transport system demonstrates we have achieved the goals of simplicity and control we are not satisfied with the size of the choosen components. However, these will be improved in future film transports by employing larger components.

After the table was assembled we found it took 300 in. oz. of torque to accelerate the film and 130 in. oz. to maintain a slew mode of operation. This requires the operator to crank at 140 rpm. According to "Human Engineering Guide to Equipment Design" the minimum force that should be transmitted through a hand crank is 2 pounds and the maximum should be 5 pounds. Thus the maximum design torque should be 120 in. oz. for the 1 1/2 inch crank radius used on our table. The minimum design torque should be 48 in. oz. We conclude from our torque measurements after building the tables and finding it difficult and tiring to transport film in a slew mode, that the radius of the hand film cranks should be increased to a 3 inch radius and the maximum crank rate for slew mode set at 140 rpm. Using these figures we would modify our design to accommodate different gearing, shafting, clutches, and braking components.

However since this information was absent from the specification a breadboard of the film drive was made to allow the customer to select and evaluate cranking the film at various rates. At this time the gear ratios and special designed crank handle was selected. It was on tests of this breadboard that we based our design. We suggest that we are partially responsible for the marginal film drive because we did not search out the human factors information upon which to base our design. However the specification did not call out these values and the COTR assumed responsibility for the human design considerations throughout the design and concurred with our approach.

The customer is presently having difficulty accepting our tables because the components are too small. We have replaced, repaired and redesigned in a continual attempt to meet their requirements and satisfy their present acceptance problems. However we recognize the real problem and have informed the customer that any further or significant improvements necessitates a major redesign.

4.4.1. General. The film transport system must be unique in that it shall permit bi-directional film motion controllable from either end, i.e., it will permit both winding and unwinding with the same crank at one end of the table. This transport system may be either mechanical or electro-mechanical; however, basic simplicity of design and complete reliability are mandatory; consequently a purely mechanical system is more desirable.

No comment

4.4.2. Film Capacity. The film transport system must be able to accommodate either single rolls of 9 1/2", 5" or 70mm wide film on either partially or fully loaded spools of up to and including 500 feet capacity. In addition, provision must be made for handling dual rolls of either 5" or 70mm film simultaneously. These rolls should be mounted side by side with a supporting post in between.

No comment

4.4.3. Film Direction. Film spools shall be located at the ends of the long dimension of the viewing area, with the film or films transported along and parallel to the long axis of the light table. When dual rolls are used, the film strips will travel parallel to each other and to the long axis of the table, with a minimum of separation between strips.

No comment

4.4.4. Rollers. Rollers must be designed so that film can be transported with either emulsion up or emulsion down without scratching either the emulsion or the base of the film. The rollers must be either segmented or some alternative system provided so that when dual rolls of film are used, alternate rolls of film can be wound in opposite directions concurrently or one of the dual rolls translated while the other roll remains stationary.

This is the only paragraph which refers to emulsion up and emulsion down. Please note that it does not indicate how the film is rolled onto the reel. After Tables 1 and 2 were delivered to the customer and while Table 3 was being checked the requirements for selective rotation direction of the reel was requested for their acceptance.

We picked up the tables previously delivered. Redesigned the circuit and provided switches which permit independant rotation selection of the top and bottom transport systems.

4.4.5. Film Tension. The film transport mechanism must maintain a light, constant, even tension on the film or films--just enough tension to keep the film flat and in contact with the plate glass surface when the film is not being transported. This tension should be automatically reduced (eased) when the film is transported.

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4.4.6. Film Drive. The film drive must provide a means of winding and unwinding single rolls of 9 1/2", 5" or 70mm wide film or dual rolls of either 5" or 70mm film. The drive must provide the ability to wind one of the dual rolls while unwinding the alternate roll or, for instance, permit one film roll or remain stationary while the other roll is translated. The drive control may be a hand crank or electric switch; however, if an electric control is used, it must permit the same degree of control sensitivity as a hand crank. If an electric drive is proposed, an additional high or "slew" speed must be provided. If a mechanical system is proposed, a two speed mechanical gear shift or electrical slew with a mechanical hand crank override will be required. In all cases, reliability of operation is mandatory. Each individual hand crank must provide very smooth winding and unwinding of film from either its own spool or the spool at the other end (long axis) of the table. The drive must be a low friction system incorporating inertia damping and antibacklash control. The effeciency, reliability, and ease of operation of this drive system is the most important single consideration in these development objectives.

Somewhere in this section of the specification there should have been a paragraph indicating the speed the film would be transported and a rate of acceleration and deceleration. In fact, after we assembled the tables and while the COTR and customer photo interpreters were checking it out, we realized the table should have dynamic braking that applies braking action only when the film starts decelerating, instead of the existing electrical clutch slipping disc brakes that brake continuously when current is applied. This change will be reflected in future units.

4.5. Tilt Mechanism

4.5.1. Amount and Direction of Tilt. The tilt mechanism must permit the table to tilt about its center from the horizontal to a position of 15° measured

Approved For Release 2002/06/17 : CIA-RDP78B04747A001400040001-2

from the vertical when rotated about the short axis. This tilt, because of the 9" overall height requirement (when in horizontal mode), may require a movable pivot point and assumes that the base is located at the edge of the table to permit the film spools and transport mechanism to extend out into space and clear the supporting surface. In addition, the light table should be able to tilt about its center, from the horizontal to 45° from the vertical when rotated about its long axis. These motions must be smooth, positive and continuously variable. Ball joints, while providing the required flexibility of motion, have not proved successful in the past.

We provided a table positioning to 90° about the horizontal position vertical angle to the base about the short axis and capable of 47 degrees about the horizontal axis from the vertical. Furthermore our table permits positioning these two angular positions simultaneously which is not in the specification. In order to provide this latter feature which the customer found desirable, we went to considerable effort in locating the power cable. Also the hand cranks used to position the table originally had non-turning handles. Because the customer objected we replaced these with rotating type hand cranks. Again this area was not defined or mentioned in the specification.

4.5.2. Tilt Lock Mechanism. A positive mechanism must be provided to lock the light table in all possible tilted and horizontal positions. This lock must be activated and deactivated with only a minimum of force and it must not lose its positive locking characteristics because of wear under continuous hard usage.

No comment

4.5.3. Electrical Wiring. All electrical wiring between the base and the light table must be carried internally or positioned where it can not be twisted or broken off. This wiring shall not interfere in any manner with the tilting motion of the table.

In order to provide for the additional convenience of tilting the table simultaneously in the vertical and horizontal axis we had to reroute the wiring.

4.5.4. Balance. The table must be completely stable and remain properly balanced throughout all the possible tilt positions, even with dual 500 foot rolls of 5" film on one end and empty spools on the other.

No comment

4.6. <u>Miscellaneous.</u>

No comment

4.6.1. Construction. Construction shall meet the highest commercial standards.

4.6.2. Shock Hazard. The unit must be grounded and be free of all shock hazard.

4.6.3. Warning Light. A warning light must be provided to show when the unit is on even if the table light intensity is turned completely down.

4.6.4. Controls. All necessary controls must be provided in locations readily accessible to the operator regardless of the degree of table tilt. Human engineering factors must be thoroughly considered in the design and placement of all necessary controls.

Since the table can be pivoted and used from either side we provided a control consolette. That can be conveniently located so the operator has access to the controls regardless of the position of the table. After we had assembled the control consolette the customer objected to the 10 turn potentiometer and micrometer knob for controlling the illumination level, this was changed to a single turn potentiometer to comply with the customer's request.

COST ITEMS NOT COVERED IN THE SPECIFICATIONS

In addition we preformed the following work or modification in building Table #1 which was not defined by the specification but resulted from talking with the customer.

1) Replacing conventional screws for special made Knurled headed screws to permit removal of the center film arms without the need for tools.

2) Our original design had the rear set of film transport arms fixed and the front film transport arm was moveable, and the center arm adjustable. We changed our design approach to one where the center arm is fixed and both the front and rear film transport assemblies were continuously adjustable when we were told two operators frequently use the same table, viewing from either side. This increased the complexity of the design, increased the number of components and increased the fabrication costs.

3) Provided an extra paralleled film crank so the tables were equally convenient to use by right or left handed personnel. Also a third crank was provided so this feature existed whether tilted about the X-X and/or Y-Y axis.

4) Added an extra switch to de-energize the film hold down bars. The customer wanted to eliminate this function if the bars proved ineffective or annoying when scanning the film slowly.

TABLE 2

DEVELOPMENT OBJECTIVES

ADVANCED FILM-VIEWING LIGHT TABLE WITH A TRANSLATING MICROSCOPE CARRIAGE

1. INTRODUCTION.

These development objectives describe the requirements to be met in the design and development of an advanced film-viewing light table with a translating microscope carriage. The proposed table would replace the current models which cannot be adjusted to accommodate different operators. The present tables are generally awkward and uncomfortable to use and do not provide adequate illumination.

Note these are development objectives or goals

2. CONCEPT.

This table is intended to provide ease of viewing, increased illumination, easy loading, an advanced film transport system and a superior method of translating a microscope over the viewing area of the table. It is to be as light, compact and simple in mechanical design as is possible within the parameters imposed by the specific requirements stated in these objectives.

No comment

3. GENERAL DESCRIPTION.

This table shall provide an 11" by 40" illuminated area for use in viewing single rolls of 9 1/2", 5" or 70mm film, or two rolls of either 5" or 70mm film. This unit will normally be positioned on an elevating or low, fixed table with the unit's viewing surface in a horizontal position, the long dimension extending to the right and left of the operator. The operator will work at the table as he would sit (or stand) at his own desk. Most operators prefer to position a viewer close to the edge nearest their side of the supporting table. A moveable carriage shall afford translation of a microscope over the viewing area.

This specifies three standard film types 9 1/2", 5" and 70mm. Since we were told they also use other film sizes our design provides continuous adjustment. Three fixed positions would have been easier but our table is more flexible in this characteristic than outlined in the specification.

4. REQUIREMENTS.

4.1. Illumination System.
After Table 1 was assembled and the customer saw the color of the lamp, he requested that the lamps for Tables 2 & 3 be made with a more blue phosphur. This wish we complied with--once again trying to provide what the customer wants and needs. However we encountered additional costs because we found this phosphur was more difficult to control the illumination variation than the previous one. Thus we had to conduct experiments once again to meet the variation in illumination requirements which envolved fabricating and testing several lamps each employing different fabrication techniques.

4.1.1. Intensity.

4.1.1.1. Range. At full intensity the illumination system must provide at least 1700 foot-lamberts measured at the illumination surface. 2000 lamberts is a definite design goal. Illumination shall not vary by more than 10% between any two points on the entire illuminated surface.

Our table provided 2200 foot lamberts of illumination at a uniformity or 6.5%. This is 11% higher illumination and 54% better uniformity than the goals set out in the specification.

4.1.1.2. Variability. The intensity of illumination shall be continuously variable through a range of 15% to 100% of full intensity without visible evidence of "flicker".

We delivered a table which provided a variable illumination of 0.45% to 100% of maximum without evidence of flicker. This is 36.5 times better than the design goal.

4.1.2. Heat. The light table must be able to be operated continuously at maximum intensity over a 24-hour period, in a room with an 80°F ambient temperature, without exceeding 110°F on any external surface.

The specification does not define the conditions under which the measurements should be made. The real problem exists when the light source is at maximum intensity and completely covered by film. Under these conditions, the heat is retained within the table and the greatest equipment temperature rise is experienced. Since we realized the problem, we have added forced ventilation. The maximum temperature of 108°F was measured in a room with 80°F ambient temperature over an 8-hour operating period.

4.1.3. Diffuser. An opal glass or similar diffuser shall be located between the light source and the clear glass top.

Our table used an acrylic plastic diffuser which is equivalent to those mentioned.

4.1.4. Shades. Adjustable shades must be provided to mask out all of the viewing surface not actually covered by film. Each of these shades must be located beneath the surface glass, mounted along the long dimension of the unit and extendible across the short dimension. This extensibility must be continuously variable between a minimum extension of (0) zero inches and a maximum extension of 9 inches. These shades must not encroach upon the illuminated viewing area when retracted and, in addition, must be able to be locked in any extended or retracted position.

We also provided a center shade to mask the space between two film strips. This added feature is an improvement but not defined in the specification.

4.2. <u>External Configuration.</u>

4.2.1. Size. The entire unit shall not exceed 55" in length and 20" in width. Width is exclusive of the crank handles but includes all the components of the translating carriage. The overall height of the light table shall not exceed 7" (minus the carriage, scope and reels). The carriage height shall be kept at a minimum.

No comment

4.2.2. Weight. The unit must be as light as possible without sacrificing good stability.

4.2.3. Height Adjustment. A superior adjustment system must be provided so that the entire table can be raised or lowered 3 inches.

4.2.4. Tilt Mechanism. A means must be provided for a 0° through 15° back-to-front tilt of the light table about its long axis. This motion must be simple, smooth, positive and must be able to be locked at any angular tilt within this range.

4.2.5. Comfortable Viewing Position. The light table, the translating carriage and the microscope adapter mounts must be designed to place each of the microscopes at a comfortable viewing height and in a comfortable working position. Human engineering factors should count strongly in the new design. It is understood, of course, that these positions also depend on the height of the illuminated surface, the requirement for the carriage to adequately clear the film and the varying working distances of the microscopes.

4.3. <u>Spool Loading and Holding Mechanism.</u>

4.3.1. Loading Mechanism. A means for the fast loading and unloading of single spools of 9 1/2", 5" or 70mm film or two rolls of either 5" or 70mm must be provided. Rolls will range up to, and including, 500-feet capacity. This loading system must operate quickly and at the same time be positive in action, i.e., it must not drop the heaviest full spool (9 1/2", 500 feet) no matter how fast or hard the film is cranked. A drop-in film loading system is desirable.

The specification was not definitive regarding the film spool type which has a direct bearing on the design of the holding mechanism.

4.3.2. Holding Mechanism. The holding mechanism which engages and secures the spool must be designed for easy one-hand operation--so that the film can be held in one hand while the holding mechanism is activated with the other. A <u>positive</u> and yet <u>quick</u> release lock must be incorporated.

This mechanism was designed and a model fabricated to demonstrate the action to the customer. This service was given to the customer but was not included in our proposal cost estimates. We did this additional work because the reel holding mechanism was one of the areas of customer concern and weaknesses in present equipment which we wanted to provide an approved solution.

4.4. <u>Film Transport.</u>

A mechanical system was designed because of the simplicity and also because it provides the operator with maximum control of the film position at all speeds. While the basic design in our film transport system demonstrates we have achieved the goals of simplicity and control we are not satisifed with the size of the choosen components. However, these will be improved in future film transports by employing larger components.

After the table was assembled we found it took 300 in. oz. of torque to accelerate the film and 130 in. oz. to maintain a slew mode of operation. This requires the operator to crank at 140 rpm. According to "Human Engineering Guide to Equipment Design" the minimum transmitted through a hand crank is 2 pounds and the maximum should be 5 pounds. Thus the maximum design torque should be 120 in. oz. for a 1 1/2 inch crank radius used on our table. The minimum design should be 48 in. oz. The maximum rpm at maximum torque should be 240 rpm. We conclude from our torque measurements after building the tables and finding it difficult and tiring to transport film in a slew mode, that the radius of the hand film cranks should be increased to a 3 inch radius and the maximum crank rate for slew mode set at 140 rpm. Using these figures we would modify our design to accommodate different gearing, shafting, clutches, and braking components.

However since this information was absent from the specification a breadboard of the film drive was made to allow the customer to select and evaluate cranking the film at various rates. At this time the gear ratios and special designed crank handle was selected. It was on tests of this breadboard that we based our design. We suggest that we are partially responsible for the marginal film drive because we didn't search out the human factors information upon which to base our design. However the specification did not call out these values and the COTR assumed responsibility for the human design considerations throughout the design and concurred with our approach.

The customer is presently having difficulty accepting our tables because the components are too small. We have replaced, repaired and redesigned in a continual attempt to meet their requirements and satisfy their present acceptance problems. However we recognize the real problem and have informed the customer that any further or significant improvements necessitates a major redesign.

4.4.1. General. A unique film transport system shall permit bi-directional film motion controllable from either end; i.e., it will permit both winding and unwinding with the same crank at one end of the table. This transport system may be either mechanical or electro-mechanical; however, basic <u>simplicity</u> of design and <u>complete reliability</u> are mandatory. Consequently, a purely mechanical system is more desirable.

4.4.2. Film Capacity. The film transport system must accommodate either single rolls of 9 1/2", 5" or 70mm-wide film on either partially- or fully-loaded spools of up to, and including, 500-foot capacity. In addition, provision must be made for handling two rolls of either 5" or 70mm film simulteneously. These rolls should be mounted side by side with a supporting post in between.

4.4.3. Film Direction. Film spools shall be located at both ends of the long dimension of the viewing area, with the film or films transported along (and parallel to) the long axis of the light table. When two rolls are used the film strips will travel parallel to each other and to the long axis of the table, with a minimum of separation between strips.

4.4.4. Rollers. Rollers must be designed so that film can be transported either emulsion-up or emulsion-down without scratching. Either the rollers must be segmented or some alternative system provided so that when two rolls of film are used, the alternate rolls can be wound in opposite directions concurrently or one of the two rolls translated while the other roll remains stationary.

This is the only paragraph which refers to emulsion up and emulsion down. Please note that it does not indicate how the film is rolled onto the reel. After Tables 1 and 2 were delivered to the customer and while Table 3 was being checked the requirement for selective rotation direction of the reel was requested for their acceptance.

We picked up the tables previously delivered. Redesigned the circuit and provided switches which permit indepent rotation selection of the top and bottom transport systems.

4.4.5. Film Tension. The film transport mechanism must maintain a light, constant, even tension on the film or films--just enough to keep the film flat and in contact with the plate glass surface when the film is stationary. This tension should be automatically reduced or eased when the film is moved.

STATINTL

To insure the cupped films obtained from remote sensors are flat, we added a hinged glass plate beneath the traveling microscope carriage which can be manually raised and lowered. We believe solving the problem of flattening cupped film was beyond the scope of this contract and was definitely not mentioned in the specification. Once again this illustrates our effort to co-operate and try to provide the customer with what he wants and needs. The specification does not provide the specific flatness requirements necessary for making measurements with high powered microscopes having a small depth of focus.

4.4.6. Film Drive.

Somewhere in this section of the specification there should have been a paragraph indicating the speed the film would be transported and a rate of acceleration and deceleration. In fact, after we assembled the tables and while the COTR and customer photo interpreters were checking it out, we realized the table should have dynamic braking that applies braking action only when the film starts decelerating, instead of the existing electrical clutch slipping disc brakes that brake continuously when current is applied. This change will be reflected in future units.

4.4.6.1. Drive Modes. The film drive must: wind and unwind single rolls of 9 1/2", 5" or 70mm-wide film or two rolls of either 5" or 70mm film; be capable of winding one of the dual rolls while unwinding the alternate roll and/or permit one roll to remain stationary while the other roll is translated.

4.4.6.2. Drive Control. The drive control may be a hand crank or electrical switch; however, if an electrical control is used, it must provide the same degree of control sensitivity as a hand crank.

4.4.6.3. Reliability and efficiency. Whatever the system, it must be very reliable. Each individual hand crank must wind of unwind film very smoothly--from either its own spool or the spool at the other end of the table. The drive must be a low-friction system which incorporates inertia damping and antibacklash features. The efficiency, reliability and ease of operation of this drive system is one of the most important considerations in this development.

4.5. Translating Microscope Carriage.

4.5.1. General. A carriage shall be provided for translating a stereo-microscope or microstereoscope in both X- and Y-directions over the illuminated format.

No comment

4.5.2. Amount of Translation. The optical center of the microscope shall scan an area of 10" by 35". This area shall be centered in the illuminated area, across the short dimension, and shall commence one-half inch from the right-hand edge of the illuminated area. (The right-hand edge refers to the operator's right as he faces the light table.)

No comment

STATINTL

4.5.3. Adapters must be provided for mounting three separate microscopes [redacted] They must permit a rapid but stable mounting of any of the above units (with their attendant focusing mechanisms) upon the translating carriage. In addition, this mounting must permit an 180° rotation of each scope so that it may be used parallel to either the X- or Y-axis of the light table and from either long side.

The specification was not definitive regarding the exact microscope auxillary lens units that were considered. During the design of the carriage, the carriage height became a problem when the 3 stereoscope types and all auxillary lens were considered. This was not known at the time of preparing our proposal and resulted in additional design effort to reduce the mensuration table height so all lens combinations could be utilized.

4.5.3.1. Carriage Motion. The carriage motion must be a smooth, positive, low-friction motion which is free of vibration ("chatter"). The friction load must be consistent throughout its range; i.e., a consistent pressure results in a consistent motion with no position of lesser or greated resistance.

There was a requirement in the mind of the customer as to how much pressure was desirable to move the carriage transport, but it was not called out in the specification. Fortunately we were able to adjust the friction to meet his requirements after the unit was built. This turned out to be 2 oz. of force.

4.5.3.2. Locks. Positive locks must be provided to lock the carriage in X and Y at any position of its 10" by 36" travel.

After Table #2 was assembled the customer objected to location of the forward X-X brake knob as it interfered with the film hand crank when the two controls were directly above each other. We didn't realize this was objectionable since it didn't interfere with using the carriage assembly, and the carriage assembly can be repositioned if the operator wants to crank film. But since it was not what the customer expected, we added a gear train to the forward X-X brake and raised the brake knob.

4.5.3.3. Fine Micrometer Motion. A fine micrometer X- and Y-microscope motion must be provided. The total travel of this motion must be $\pm$2cm. in both X and Y. This motion shall be a precision, auxiliary motion accomplished once the main translational carriages have been locked in position. This precision motion must be graduated and easily readable. The motion shall be accurate to .001mm plus .01% of the total distance being measured with a least count of .001mm.

4.5.3.4. Rigidity. It is mandatory that the carriage ways be of rigid construction to insure perpendicularity of the X- and Y- axis. These ways (or tracks) must be perpendicular and parallel to the extent that, when one end of the Y track is locked (so that it can not move in X) and a pressure of 5 pounds is applied to the other end (longest possible lever arm) of the Y track, it will not deflect more than .002 inches.

4.6. Miscellaneous.

4.6.1. Construction. Construction shall meet the highest commercial standards.

4.6.2. Shock Hazard. The unit must be grounded and free of all shock hazards.

4.6.3. Warning Light. A warning light must be provided to show when the unit is on even if the (table) light intensity is turned completely down.

4.6.4. Controls. All operational controls must be conveniently located and readily accessible to the operator. Human engineering factors must be thoroughly considered in the design and placement of these controls.

Since the table is very long and the operator may be working at either end, we provided a separate control consolette.

COST ITEMS NOT COVERED IN THE SPECIFICATIONS

1) Recessing the X-X carriage bars on Tables 2 & 3 so they would not be in the operators way as well as collect less dust. We found this to be a very expensive change because of the increased design complexity and manufacturing costs.

2) Providing interlock switches to prevent the carriage from interferring with the hold down bars when they were in the off position or if the

film was translated when the carriage was positioned to the far right or far left where it would be over the hold down bars.

3) Providing an extra paralleled film crank so that the tables were equally convenient to use by right or left handed personnel.

TABLE 3

DEVELOPMENT OBJECTIVE

ADVANCED FILM-VIEWING LIGHT TABLE WITH TRANSLATING MICROSCOPE CARRIAGE AND HIGH-INTENSITY TRACKING LIGHT SOURCES

1. INTRODUCTION.

These development objectives describe requirements to be met in the design and development of an advanced film-viewing light table with a translating microscope and integral, high-intensity, tracking light sources.

Note these are development objectives or goals

2. CONCEPT.

The proposed light table will improve viewing with translating stereomicroscopes or microstereoscopes. It incorporated features for ease of viewing and two high-intensity condenser-type light sources for the optimized narrow field illumination required for 30X-150X magnification viewing. These light sources shall incorporate an advanced tracking system to permit them to retain proper alignment with the microscope as the operator scans the film.

No comment

3. GENERAL DESCRIPTION.

This table shall provide an 11" by 40" illuminated area for use in viewing single rolls of 9 1/2", 5" or 70mm film, or two rolls of either 5" or 70mm film. This unit will normally be positioned on an elevating or low, fixed table with the unit's viewing surface in a horizontal position, the long dimension extending to the right and left of the operator. The operator will work at the table as he would sit (or stand) at his own desk. Most operators prefer to position a viewer close to the edge of their side of the supporting table. A movable carriage shall afford translation of a microscope over the viewing area, while dual, independently adjustable, condenser-type light sources track the moving microscope.

This specifies three standard film types 9 1/2", 5", and 70mm. Since we were told they also use other film sizes our design provides continuous adjustment. Three fixed positions would have been easier but our table is more flexible in this characteristic than outlined in the specification.

4. REQUIREMENTS.

4.1. Illumination Systems.

After Table 1 was assembled and the customer saw the color of the lamp, he requested that the lamps for Tables 2 and 3 be made with a more blue phosphur. This wish we complied with--once again trying to provide what the customer wants and needs. However, we encountered additional costs because we found this phosphur was more difficult to control illumination variation than the previous one. Then we had to conduct experiments once again to meet the variation in illumination requirements which involved fabricating and testing several lamps each employing different fabrication techniques.

4.1.1. General Illumination. To facilitate general viewing and small image location, the total 11" by 40" glass format shall be illuminated by fluorescent-type illumination.

4.1.1.1. Intensity Range. At full intensity, the general illumination system must provide at least 1000 foot-lamberts measured at the illumination surface. Illumination shall not vary by more than 10% between any two points on the entire illuminated surface.

Our illumination system provided 2000 foot lamberts of intensity at a uniformity of 6.5%. This is a 200% higher illumination than defined in the specification and 54% better uniformity than the goals defined in the specification.

4.1.1.2. Variability of Intensity. The intensity of illumination shall be continuously variable through a range of 15% - 100% of full intensity without visible evidence of "flicker."

We delivered a table which varied the illumination from 2000 to 8 foot lamberts. This is a variation from 0.4% to 100% of maximum illumination without evidence of flicker. This is 37.5 times better than the specified design goal.

4.1.1.3. Heat. The general illumination source must be able to be operated continuously at maximum intensity over a 24-hour period, in a room with an 80°F ambient temperature, without exceeding 110°F on any external surface of the light table.

The specification does not define the conditions under which the measurements should be made. The real problem exists when the light source is at a maximum intensity and completely covered by hi-density film. Under these conditions, the heat is retained within the table and the greatest equipment temperature rise is experienced. Since we realized the problem, we have added forced ventilation. The maximum temperature of 108°F on the glass in contact with the film was measured in a room with 80°F ambient temperature over an 8-hour operating period.

4.1.1.4. Diffuser. An opal glass or similar diffuser shall be located between the light source and the clear glass top.

Our table used an acrylic plastic diffuser which is equivalent to those mentioned.

4.1.1.5. Shades. Adjustable shades must be provided to mask out all of the viewing surface not actually covered by film. Each of these shades must be located beneath the surface glass, mounted along dimension of the unit and extendable across the short dimension. This extensibility must be continuously variable between a minimum extension of (0) zero inches and a maximum extension of 9 inches. These shades must not encroach upon the illuminated viewing area when retracted and, in addition, must be able to be locked in any extended or retracted position.

We also provided a center shade to mask the space between two film strips. This added feature is an improvement but not defined in the specifications.

4.1.2. High-Intensity Illumination System.

We studied the problems associated with the tracking light sources and concluded the specified incandescent light sources would be too bulky, have a short life (approximately 50 hours) at maximum intensity, and mask off an excessive amount of the general illumination area. Laboratory tests were performed to define that an intensity of 3500 foot lamberts was required. We proposed to the customer to change the requirement from incandescent to flourescent high intensity sources which has provided the following improved features:

1. Simplicity in construction which will lead to lower production costs.
2. Longer bulb life estimated to be about 1000 hours.
3. Provides a constant color temperature over a wider dimming ratio.
4. Allows a smaller distance between the general illumination system and the film surface because of the shallow depth of the flourescent lamp.
5. The proposed flourescent lamp will provide a larger area of high intensity light than two 40 mm incandescent sources thereby eliminating the problem of precision tracking. This method should be simpler, more reliable, and inexpensive to build in production than an incandescent tracking light source technique.
6. We incorporated a park position for the tracking light source assembly that allows practically the entire general illuminated area for scanning the film. This was not required in the original design specification but does prove we gave the customer the best unit possible.
7. The design specification called out a minimum of 50 mm separation between the two 40 mm tracking light sources. The flourescent lamps provide a separation distance of only 12.7 mm between the two sources.
8. Three high intensity sources were provided instead of two. We believe this will be more versatile and much easier to change from direct to 90° rotation position of the microscope.
9. Each of the three lamps has an independant switch to permit any combinatio of AB, AC, or BC. This is an advantage because a new stereoscope with wider rhomboidal separation not described in the technical specification can be used on this table. This additional feature was added after the consolette was wired once again to give the customer what he wanted.
10. We delivered a high intensity light sources having maximum intensities of 4000, 4000, and 4500 foot lamberts.
11. These lamps were dimable from 100% to 25% of their maximum value. This is an improvement of 2 times better than the specified 100% to 50% variation.

4.2 through 4.2.5 no comment

4.3.1. Loading Mechanism. A means for the fast loading and unloading of single spools of 9 1/2", 5" and 70mm film or two rolls of either 5" or 70mm must be provided. Rolls will range up to, and including, 500-feel capacity. This loading system must operate quickly and at the same time be positive in action:

i.e., it must not drop the heaviest full spool (9 1/2", 500 feet) no matter how fast or hard the film is cranked. A drop-in film loading system is desirable.

Spool Loading and Holding Mechanism--The specification was not difinitive regarding the film spool type which has a direct bearing on the design of the holding mechanism.

4.3.2. Holding Mechanism. The holding mechanism which engages and secures the spool must be designed for easy one-hand operation--so that the film can be held in one hand while the holding mechanism is activated with the other. A positive and yet quick release lock must be incorporated.

This mechanism was designed and a model fabricated to demonstrate the action to the customer. This service was given to the customer but was not included in our proposal cost estimates. We did this additional work because the reel holding mechanism was one of the areas of customer concern and weaknesses in present equipment which we wanted to provide an approved solution.

4.4.1 through 4.4.3 no comment

4.4. Film Transport

A mechanical system was designed because of the simplicity and also because it provides the operator with maximum control of the film position at all speeds. While the basic design in our film transport system demonstrates we have achieved the goals of simplicity and control we are not satisfied with the size of the choosen components. However, these will be improved in future film transports by employing larger components.

After the table was assembled we found it took 300 in. oz. of torque to accelerate the film and 130 in. oz. to maintain a slew mode of operation. This requires the operator to crank at 140 rpm. According to "Human Engineering Guide to Equipment Design" the minimum force that should be transmitted through a hand crank is 2 pounds and the maximum should be 5 pounds. Thus the maximum design torque should be 120 in. oz. for the 1 1/2 inch crank radius used on our table. The minimum design torque should be 48 in. oz. We conclude from our torque measurements after building the tables and finding it difficult and tiring to transport film in a slew mode, that the radius of the hand film cranks should be increased to a 3 inch radius and the maximum crank rate for slew mode set at 140 rpm. Using these figures we would modify our design to accommodate different gearing, shafting, clutches, and braking components.

However since this information was absent from the specification a breadboard of the film drive was made to allow the customer to select and evaluate cranking the film at various rates. At this time the gear ratios and special designed crank handle was selected. It was on tests of this breadboard that we based our design. We suggest that we are partially responsible for the marginal film drive because we didn't search out the human factors information upon which to base our design. However the specification did not call out these values and the COTR assumed responsibility for the human design considerations throughout the design and concurred with our approach.

The customer is presently having difficulty accepting our tables because the components are too small. We have replaced, repaired and redesigned in a continual attempt to meet their requirements and satisfy their present acceptance problems. However we recognize the real problem and have informed the customer that any further or significant improvements necessitates a major redesign.

4.4.1. General. The film transport system must be unique in that it shall permit bi-directional film motion controllable from either end, i.e., it will permit both winding and unwinding with the same crank at one end of the table. This transport system may be either mechanical or electro-mechanical; however, basic simplicity of design and complete reliability are mandatory; consequently a purely mechanical system is more desirable.

No comment

4.4.2. Film Capacity. The film transport system must be able to accommodate either single rolls of 9 1/2", 5" or 70mm wide film on either partially or fully loaded spools of up to and including 500 feet capacity. In addition, provision must be made for handling dual rolls of either 5" or 70mm film simultaneously. These rolls should be mounted side by side with a supporting post in between.

No comment

4.4.3. Film Direction. Film spools shall be located at the ends of the long dimension of the viewing area, with the film or films transported along and parallel to the long axis of the light table. When dual rolls are used, the film strips will travel parallel to each other and to the long axis of the table, with a minimum of separation between strips.

No comment

4.4.4. Rollers. Rollers must be designed so that film can be transported with either emulsion up or emulsion down without scratching either the emulsion or the base of the film. The rollers must be either segmented or some alternative system provided so that when dual rolls of film are used, alternate rolls of film can be wound in opposite directions concurrently or one of the dual rolls translated while the other roll remains stationary.

This is the only paragraph which refers to emulsion up and emulsion down. Please note that it does not indicate how the film is rolled onto the reel. After tables 1 and 2 were delivered to the customer and while table 3 was being checked, the requirement for selective rotation direction of the reel was requested for their acceptance. We picked up the tables previously delivered, redesigned the circuitry independant reel rotation selection of the top and bottom transport systems.

4.4.5 Film Tension. The film transport mechanism must maintain a light, constant; even tension on the film or films -- just enough to keep the film flat and in contact with the plate glass surface when the film is stationary. This tension should be automatically reduced or eased when the film is moved.

STATINTL

4.4.6 Film Drive

The film drive must provide a means of winding and unwinding single rolls of 9 1/2", 5" or 70mm wide film or dual rolls of either 5" or 70mm film. The drive must provide the ability to wind one of the dual rolls while unwinding the alternate roll, or, for instance, permit one film roll to remain stationary while the other roll is translated. The drive control may be a hand crank or electric switch; however, if an electric control is used, <u>it must permit the same degree of control sensitivity as a hand crank</u>. If an electric drive is proposed, an additional high or "slew" speed mechanical gear shift or electrical slew with a mechanical hand crank override will be require. In all cases, reliability of operation is mandatory. Each individual hand crank must provide very smooth winding and unwinding of film from either its own spool at the other end (long axis) of the table. The drive must be a low friction system incorporating inertia damping and anti-backlash control. The efficiency, reliability, and ease of operation of this drive system is the most important single consideration in these development objectives.

<u>Specification Ambiguity</u>: Somewhere in this section of the specification there should have been a paragraph indicating the speed the film would be transported and a rate of acceleration and deceleration. In fact, after we assembled the tables and while the COTR and customer photo interpreters were checking it out, we realized the table should have dynamic braking that applies braking action only when the film starts decelerating, instead of the existing electrical clutch slipping disc brakes that brake continuously when current is applied. This change will be reflected in future units.

4.5.1 and 4.5.2 No comment

4.5.3 Adapters must be provided for mounting three separate microscopes:

STATINTL [redacted] They must permit a rapid but stable mounting of any of the above units (with their attendant focusing mechanisms) upon the translating carriage. In addition, this mounting must permit an 180° rotation of each scope so that it may be used parallel to either the X- or Y- axis of the light table and from either long side.

The specification was not definitive regarding the exact microscope auxillary lens units that were considered. During the design of the carriage, the carriage height became a problem when the three stereoscope types and all auxillary lens were considered. This was not known at the time of preparing our proposal and resulted in additional design effort to reduce the mensuration table height so all lens combinations could be utilized.

4.5.3.1 Carriage Motion. The carriage motion must be a smooth, positive, low-friction motion which is free of vibration ("chatter"). The friction load must be consistent throughout its range, i.e., a consistent pressure results in a consistent motion with no position of lesser or greater resistance.

There was a requirement in the mind of the customer as to how much pressure was desirable to move the carriage transport, but it was not called out in the specification. Fortunately we were able to adjust the friction to meet his requirements after the unit was built. This turned out to be 2 oz. of force.

4.5.3.2. Locks. Position locks must be provided to lock the carriage in X and Y at any position of its 10" by 36" travel.

After Table #2 was assembled, the Customer objected to location of the forward X-X brake knob as it interfered with the film hand crank when the two controls were directly above each other. We didn't realize this was objectionable since it didn't interfere with using the carriage assembly, and the carriage assembly can be repositioned if the operator wants to crank film. But since it was not what the Customer expected, we added a gear train to the forward X-X brake and raised the brake knob.

4.5.3.3 through 4.6.3 No comment

4.6.4 Controls. All operational controls must be conveniently located and readily accessible to the operator. Human engineering factors must be thoroughly considered in the design and placement to these controls.

Since the table is very long and the operator may be working at either end, we provided a separate control consolette.

COST ITEMS NOT COVERED IN THE SPECIFICATION

1) Recessing the XX carriage bars on Tables 2 & 3 so they would not be in the operators way as well as collect less dust.

We found this to be a very expensive change because of the increased design complexity and [illegible]

2) Providing an extra paralleled film crank so that the tables were equally convenient to use by right or left handed personnel.

3) Addition of a gear train to Table #2 and #3's forward brake on the Microscope Carriage Assembly. This was added for operator convenience as it gives him a "feel" when the brake is being applied and will help him make accurate measurements. Also the gear train raises the brake torque knob and allows film to be transported regardless of the position of the carriage assembly.

4) The tracking light source and microscope carriage assembly have a spring added so these assemblies return automatically to the rear of the light table when not used.

5) The customer asked us to change the paint color on Table #3 after seeing it on the first two tables. We made the change even though the paints for this table had been released to the shop for fabrication. This amounted to a large paper work effort since we had to recall all the prints, change the finish and resubmit them to the shop again in addition to buying the new paint.